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A STUDY OF THE DUST HAZARD IN THE WET AND DRY GRINDING SHOPS OF AN AX FACTORY.

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The Development of the Ax-Making Industry in the United States.

In Bolles's Industrial History of the United States (1881) there is a quaint and picturesque description of the history of the ax industry in America, which runs as follows:

"Until within 50 years the axes used in America were imported. A few rude blades were forged at the blacksmith shops by village greens, but the business was of so little account that it was not thought worthy of protection by Congress. During the Revolution and the War of 1812, when the United States were cut off from their principal source of supply for manufactures of iron and steel, axes were largely made by the American blacksmiths, but the return of peace brought fresh importations, which checked the industry again. No tax was levied by Congress on an article of such extended use in the United States and so indispensable to the development of the country. The first ax shop in the country was started by Samuel W. and D. C. Collins, of Hartford, Conn., in 1826. They thought that there was a field for the manufacture of axes here and they put up a little stone trip hammer shop with a capacity of eight axes a day and began drawing patterns and forging and tempering blades. In 1828 Congress levied a duty of 35 per cent on axes to assist the dawning industry. The Collins moved to Collinsville, Conn., and opened a large factory which, after some years, passed into the hands of a company called Collins & Co. The business has since grown to gigantic proportions and world-wide celebrity. After the Collins's shops were opened others were started, the principal ones of which are now the Douglas Ax Co., of East Douglas, Mass., and the concern at Cohoes, N. Y. The Collins factory is the largest in the world; it employs from 450 to 550 men, produces 2,000 axes, sledge hammers, and cast-steel tools a day, and consumes in the course of the year 1,800 tons of iron, 350 of cast steel, and 7,000 of coal.

"The process of ax making is full of interest, indeed, it is exciting during some stages of the manufacture. The first operation consists in clipping from long, flat bars a half foot of American iron, which is

quickly transformed into the poll of an ax, which is merely the head and eye and about half of the blade, the balance or cutting part of the blade being composed of nearly a pound of the best Jessop steel, so inlaid with the iron that the tool may endure years of grinding and still retain its fine steel edge. Other kinds in the market can boast of a greater spread of steel surface, but they are entirely innocent of that sort of 'northern iron,' as the prophet Jeremiah terms it, in the center of the tool, which will enable it to stand the hard usage in store for it. The real difference between the two metals is finely brought out in the polishing process, in which no amount of furbishing can leave that fine surface on the iron which the steel readily takes and which forms a perfect mirror in the finished implement.

"Passing over a variety of intermediate handlings, in which the essential objects obtained are complete welding of the two metals and perfect symmetry in the several patterns made (all of which are accomplished amid the distractions of an army of large and small trip hammers, whose din at times is well-nigh deafening to an outsider), we reach the tempering room, where a score or so of men are occupied in bringing the steel to the proper degree of hardness—a point requiring the utmost nicety of attention. Small furnaces are kept burning on the iron tables of the workmen (or watchmen, rather, for about all they do is to keep a keen eye on the color assumed by the iron), and the instant the right hue is developed, the ax goes into a salt-water bath, which fixes the carbonized state of the iron forever, unless again put through the fiery torture.

"The next stage in the progress of the ax toward completion brings us to the grinding and polishing departments. Some idea of the relative importance of this branch of the manufacture may be had from the fact that it costs $100 worth of grindstones daily to bring the ax to the marketable stage, to say nothing of the immense expenditure of emery in polishing afterwards. Huge stones from Nova Scotia and the West lie about the shopyards, full 7 feet in diameter many of them; and in no longer than three week's time they are used up. Many of the men ride on 'horses' while grinding, thus enabling them to bring their whole bodily avoirdupois to aid the process of abrasion, while the fine dust flies in clouds from the stones in every direction, notwithstanding the stones are all the time completely deluged with water.

"The men in this section are, from their peculiarly hazardous work, ruled out of all the life insurance companies; since the constant inhalation of the grit and bits of steel thrown off in the process induces the 'grinders' consumption,' as it is rightly termed, from which a premature death is rarely averted. It is said that Americans will not work in these rooms, which are filled by French Canadians who stop a few years, and then go home to linger a while and die."

Industrial Tuberculosis Among Ax Grinders.

It will be noted that Bolles assumes "grinders' consumption" to be a characteristic hazard of the ax grinders' trade. The factory at East Douglas, Mass., has in the past been famous as a hotbed of this disease. The senior author has a letter written by a local physician, which describes the situation as follows:

"I have seen quite a number of cases of so-called grinders' consumption. The symptoms are excessive shortness of breath on slight exertion, dry cough and great prostration. The grinders are from the Polanders and Finns for the past dozen years. The disease takes hold of them more frequently and is more rapidly fatal than among the grinders of former years and of other nationalities. When I came here 40 years ago I found the victims among the Yankees who had ground some 20 years before. Those could grind 18 or 20 years before having to give it up. The French-Canadians were then grinding. They could work 12 to 16 years. They became frightened off and the Swedes took up the work. They would get the disease in 8 or 10 years. Now the Finns and Polanders are at it, and they last only 3 to 5 years, and the disease is more common among them."

In spite of these alarming implications no intensive study of the industrial hazard of ax making has, so far as we are aware, been made in the United States. We therefore welcomed the opportunity which offered in the fall of 1919 to undertake such a study in a large establishment in the State of Connecticut, devoted to the manufacture of axes and other edge tools.

An essential part of the investigation consisted in an exhaustive statistical study conducted by Dr. Herbert Drury, on the incidence of tuberculosis among the grinders and polishers in the ax factory as compared with other employees of the factory and with the populations of adjacent towns and of the State of Connecticut as a whole. This study of Dr. Drury's, which will be published shortly, reveals results which are almost sensational in character. Dr. Drury's figures show an average tuberculosis death rate for the period 1900–1918, inclusive, for male persons in Connecticut, of 1.7 per 1,000, for the employees other than polishers and grinders in the factory studied, of 1.6, and for the polishers and grinders in the ax factory, a rate about ten times higher.

This excess death rate of over 1,000 per cent occurs in a group including some 90 polishers, about 85 wet grinders, and about 25 dry grinders. It is surprisingly high in view of the fact that the polishing and dry grinding shops are equipped with excellent exhaust systems for the protection of the workers, and in view of the general assumption by authorities on industrial hygiene that wet grinding is a process relatively free from harmful atmospheric dust.

It was impossible in Dr. Drury's statistical study to distinguish between polishers and grinders because it is common for grinders who fail in health to be transferred to the polishing shops, where they are usually able to work for some years longer. It seems certain, however, that the chief hazard must lie in grinding rather than in polishing; and this means that there are some forms of wet grinding that are by no means the harmless process they have been assumed to be, for wet grinding was the only type carried on in this factory until three years ago, and even in 1919 there were only 25 dry grinders as against 86 wet grinders.

It seems obvious that an intensive study of the actual air conditions in wet grinding shops is eminently desirable, for if the confidence commonly placed in the protective influence of moisture on the grinding wheel be misplaced, the real facts should be made clear to the manufacturer and the sanitarian.

Thackrah ("The Effects of the Principal Arts, Trade, and Professions on Health and Longevity," 1831) states that "fork grinders (at Sheffield), who use a *dry* grindstone, die at the age of 28 or 32, while the table-knife grinders, who work on *wet* stones, survive to between 40 and 50;" and Herbert Lush (Parliamentary Paper Cd 4913, London, 1909) maintains that both wet and dry grinders suffer from a marked excess of respiratory disorders. Most writers, however, draw a much sharper distinction between the hazards involved in the two processes. James H. Lloyd in his article on diseases of occupations in the *Twentieth Century Practice of Medicine* (1895) says, in comparing wet and dry grinding, "the latter method is by far the more injurious, as naturally it raises far the greater amount of dust." Sir Thomas Oliver in his "Diseases of Occupation" (1908) says "the dry method is, from a health point of view, the more dangerous to the workers,[1] and later, "In wet grinding the running stone passes through a thin layer of water in a trough below the stone, so that, as its surface is always kept wet, comparatively little dust is given off during the process of grinding." G. M. Price in *The Modern Factory* (1914) states that "wherever material is broken up, ground, milled, polished, powdered, comminuted, or worked over in whatsoever manner, there dust can be prevented from forming by the simple addition of water, oil, or other appropriate liquid. The waterspout over a grinding wheel is an example of the wet process of grinding." Dr. W. Gilman Thompson ("The Occupational Diseases," 1914) maintains that "Dust formation may be checked by sprays or jets of water, steam, or oils in many industries like rock drilling, pottery cleaning, brickmaking, metal grinding, etc., where the nature of the substance dealt with permits

[1] It should be noted that in the past the workers in dry grinding shops were not protected by exhaust systems, as they are to-day. In the absence of such protection dry grinding would naturally be more hazardous than wet grinding.

the application of moisture without injury to the product. In fact, in many forms of drilling and grinding the moisture lessens friction and is an advantage to the process. Its application is usually easy and inexpensive and should be made wherever practicable."

The chief object of the present study was to discover by actual determinations of the dust content of the air whether or not the process of wet grinding really involves a serious hazard of industrial tuberculosis, as Dr. Drury's statistics would appear to indicate.

Description of Processes Carried On in the Ax Factory Under Investigation.

The factory in which we had the opportunity of studying this problem is one of the largest of its kind in the United States. It includes a considerable group of buildings, steel shops, forge shops, tempering shops, and a plow shop, as well as the polishing and grinding shops, in which we were particularly interested. The employees number about 800, of whom about 200 are grinders and polishers, the majority of the remainder being steel makers and forgers. The articles manufactured are chopping axes of almost every conceivable pattern, plows, hammers, wrenches, picks, grubbing hoes, brush hooks, broadaxes, hatchets, and machetes. The process of ax manufacture, being the one of particular significance, is the only one that need be described in detail.

In the making of axes at this plant three types of steel are used: (1) blister steel, (2) high carbon crucible steel, and (3) low carbon steel. The blister steel is a special type of steel containing a very large amount of carbon and, when mixed in proper proportions with low carbon steel (manufactured from scrap metal), the mixture forms the high carbon crucible steel.

In making an ax the bars of low carbon steel are cut into the proper lengths and the pieces of metal (about 12 inches long, 3 inches wide, and 1 inch thick) are heated and passed between rolls which form them into a "blank." The blank differs from the bar chiefly in the fact that the central portion (which is to make up the eye of the ax) has been thinned down to about half its original thickness. The blank is then heated and bent over into a U shape, the open ends of which are welded together to form the body of the ax blade, the thin portion at the base of the U remaining separate to form the eye. Before the final welding of the blade, however, a piece of high carbon crucible steel is inserted between the two ends of the U to form the cutting edge of the blade. The whole piece is then given a small amount of forming with the trip-hammer and the edge of the ax is trimmed to form with a bench cutter.

The ax is then transported to a drop shop, where the eye is reamed (hot) by forcing a shaped piece of steel through it under a power press, and then, with this piece of steel occupying the place which later will be given over to the handle, the ax is forged under a drop-

hammer and the eye-former removed. The ax is then passed to a worker who cuts off the fin by means of a high-speed steel saw, the metal being at a light red heat at the time.

The ax is next ground (to remove all surface scale and smooth the tool). After grinding, the ax goes to the hardening and tempering room, where it is heated in a large oven on a revolving rack. It is then cooled or chilled on a revolving rack in a salt water bath, washed in clear water, and is then ready for tempering. In this process it is heated to redness and cooled in air. The ax is now polished, the head portion painted either red or black, and the ax wrapped in paper ready for boxing.

The grinding of the axes and other tools in this factory is performed by the use of huge stones of three different varieties, all natural sandstones of practically pure silica.

A stone of 72 inches in diameter weighs approximately 2 tons. One 84 inches across weighs 3 tons. Stones vary greatly in thickness, viz, from 8 to 13 inches, an ax or a tool stone usually being about 11 inches, while that used for machetes is about 13 inches wide. A stone 70 inches by 12 inches, used to grind axes and tools, will last about one month, while that used for machetes will last three months. Stones are discarded when they reach a diameter of 29 inches. From 40 to 50 stones on an average are used up each month throughout the year.

A stream of water from an inch pipe is continuously thrown upon the stone, which is thus kept wet during the grinding process. This stream of water may be regulated or entirely shut off. The men are paid by the piece, and it is quite apparent that they are aware that a moist stone will grind much faster than a very wet one, even if it does generate and distribute more dust.

An ax which weighed 4 pounds 12 ounces when brought to the grinding shop, weighed 4 pounds 3 ounces after the process of grinding was completed, which represented a loss of 9 ounces of iron and steel in the form of minute particles. On the average, a man can grind an ax in from three to five minutes. Thus, if this 9 ounces was multiplied by the average number of axes ground by each man daily, and that again by the number of men thus employed in the shop, it will be found that several hundred pounds of iron and steel are cast off daily in the finely divided state.

Dust Content of the Air in the Dry-Grinding Shop.

In order to obtain an idea of the actual condition of the air breathed by the dry grinders, 10 different samples were collected from the dry-grinding shop on two different occasions. These samples were collected by the use of the Palmer Water Spray Apparatus and examined by the methods recommended by the Committee on Standard Methods for the Examination of Air of the American Public Health

Association (*American Journal of Public Health,* Vol. VII, p. 54, and Vol. X, p. 450). Sampling points were always so chosen as to be as nearly as possible representative of the air actually respired by the workmen. The apparatus was protected from the splashing of dust-laden water by means of a piece of cardboard placed in front of the air intake.

TABLE 1.—*Dust Analyses—Dry-grinding shops.*

Sample number.	Date.	Number of particles per cubic foot of air.		Weight of total dust, milligram per cubic foot of air.	Per cent of inorganic dust.
		One standard unit.	One-fourth standard unit.		
1041	Jan. 4	11,800	192,000	0.083	89.4
1042	...do	5,100	150,000	.057	80.5
1043	...do	2,200	81,000	.019	....
1044	...do	1,500	51,500	.045	80.3
1045	...do	1,500	71,000	.026	88.8
1046	...do	2,450	54,000	.021	71.2
2101	Feb. 10	5,300	206,000	.072	100.0
2102	...do	6,200	400,000	.101	100.0
2103	...do	7,300	220,000	.033	97.4
2101	...do	7,000	120,000	.031	99.7
Average	....	....	154,500	0.0548	....

Table 1 shows the results of analyses of dust obtained from the air of the dry-grinding shop. An examination of this table reveals the fact that the number of dust particles of a size of 10 microns and under (that size designated in our table as one-fourth standard unit, and the size recognized as of most serious sanitary significance) varies from 51,000 to 400,000 per cubic foot of air and averages 154,500, while the weight of the dust varies from 0.019 to 0.101 milligram per cubic foot of air and averages 0.055 milligram per cubic foot. At the present time the only standards for the dust content of the air of grinding and polishing shops, based on actual quantity of dust in the air, are those proposed by us in a paper entitled "Standards for measuring the efficiency of exhaust systems in polishing shops," PUBLIC HEALTH REPORTS, March 7, 1919.

In this study it was suggested that "the weight of dust in the air of a polishing shop can, with an efficient exhaust system, be kept constantly below 0.06 milligram per cubic foot and should not average over 0.03 milligram," * * * and "that the dust content of the air of a polishing shop can be kept generally under 300,000 one-fourth standard unit particles per cubic foot and should not average over 200,000."

Judged by these standards one is forced to the conclusion that the air of the dry-grinding shop in question contains such a minor amount of impurities as to justify us in saying that it is comparatively free from industrial hazard. The weight of dust, it will be observed,

is somewhat in excess of that proposed in the standard, but this is without doubt due to the presence of those large particles of dust which are of no great sanitary significance.

Dust Content of the Air in the Wet-Grinding Shop.

Table II presents a summary of the analyses of 32 samples of dust obtained from the air of four wet-grinding shops on seven different days, and here the picture is a very different one. The average number of particles of the one-fourth standard unit size was found to be 15,800,000, and the weight to be 0.414 milligram per cubic foot. These are amounts greatly in excess of the standards previously referred to and are comparable only with dust contents previously recorded by us in abrasive factories (PUBLIC HEALTH REPORTS, May 30, 1919) and in the interior of a sand-blast cabinet (PUBLIC HEALTH REPORTS, Mar. 5, 1920). Since the dust present is of such a high inorganic content and the particles are so minute (practically all being 1 or 2 microns in diameter) and are present in such enormous numbers, one is forced to the conclusion that, judged by our present knowledge on this subject, the dusty condition of the air of these wet-grinding shops constitutes a most serious hazard to the health of the worker.

TABLE II.—*Dust analyses—Wet-grinding shops.*

Sample No.	Date.	Number of particles per cubic foot of air.		Weight of total dust, milligrams per cubic foot of air.	Per cent of inorganic dust.
		One standard unit.	One-fourth standard unit.		
3221	Mar. 22	9,000	11,100,000	0.287	99.9
3222	...do	44,000	15,300,000	.397	97.3
3223	...do	29,000	18,100,000	.444	99.9
3241	Mar. 24	39,300	16,000,000	.294	98.5
3242	...do	81,500	21,500,000	.528	98.6
3243	...do	20,000	12,600,000	.197	98.6
3244	...do	13,300	8,300,000	.187	98.1
3291	Mar. 29	27,000	39,200,000	1.089	97.6
3292	...do	60,000	18,800,000	.760	96.8
3293	...do	105,000	50,000,000	2.160	....
3294	...do	32,500	9,500,000	.206	97.8
3295	...do	12,500	5,500,000	.103	91.0
4061	Apr. 6	15,000	7,200,000	.176	94.5
4062	...do	33,000	9,600,000	.244	96.8
4063	...do	15,000	5,100,000	.136	95.2
4064	...do	....	870,000	.079	90.4
4065	...do	11,100	1,900,000	.083	91.8
4091	Apr. 9	19,000	15,800,000	.213	97.3
4092	...do	41,000	21,700,000	.278	98.2
4093	...do	37,000	25,300,000	.372	99.3
4094	...do	39,000	22,000,000	.272	97.0
4095	...do	10,000	4,700,000	.088	93.3
4141	Apr. 14	....	6,200,000	.116	97.1
4142	...do	42,000	6,900,000	.121	96.7
4143	...do	208,000	20,000,000	.476	96.5
4144	...do	50,000	20,900,000	.520	98.1
4145	...do	32,800	17,600,000	.420	96.4
4201	Apr. 20	....	8,700,000	.132	94.3
4202	...do	....	24,100,000	.413	96.3
4203	...do	202,000	17,600,000	.580	97.3
4204	...do	82,000	24,000,000	1.241	98.6
4205	...do	99,000	19,400,000	.623	98.4
Average	....	....	15,800,000	0.414	....

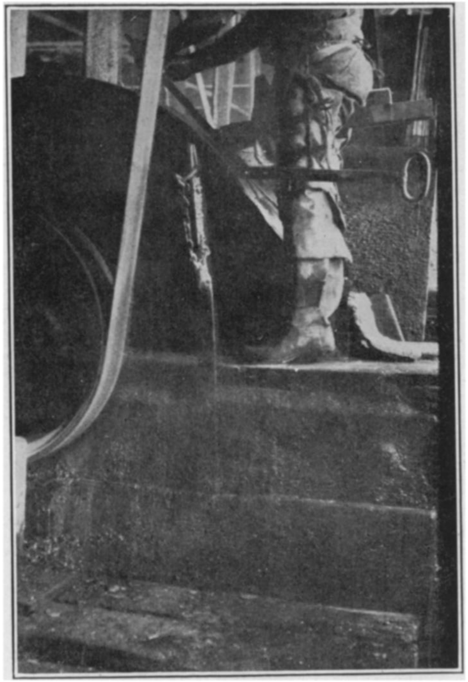

FIG. 1.

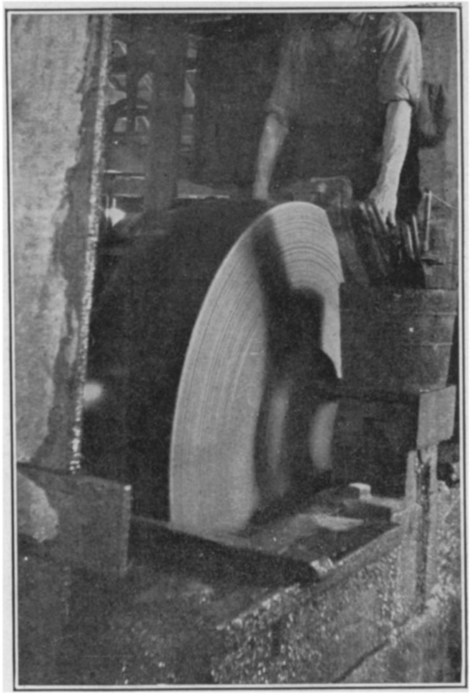

FIG. 2.

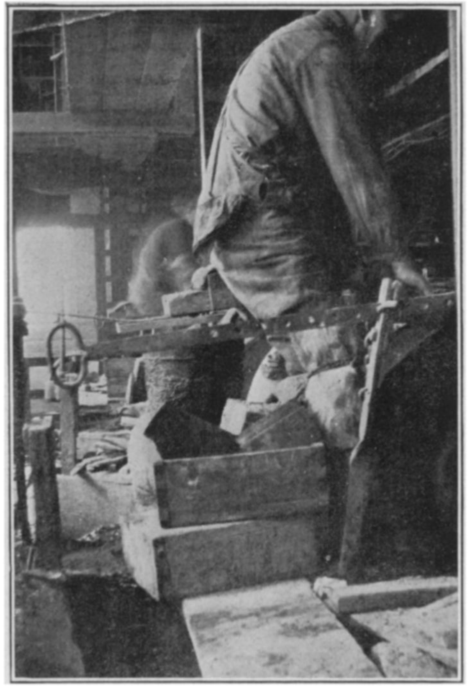

FIG. 3.

INTERIOR OF WET-GRINDING SHOP.

FIG. 1.—This workman is grinding a machete. The picture shows how the whole body weight of the workman may be utilized in accelerating the process of grinding.

FIG. 2.—The grinder holds the ax by means of a short stick passed through the eye. The bucket holding these sticks also contains water, in which he dips the ax and washes it off in order to examine the edge. The suspended board acts as a mud guard for passers-by.

FIG. 3.—In the process of wet grinding, the worker rides a "horse." Note the upright to which is clamped a horizontal flat steel bar, the end of which projects over a portion of the stone. The workman fastens his saddle to the steel spring and sits astride of this. To grind quickly, he places the ax under the end of the spring and then brings his whole weight to bear upon it, so that a cloud of dust and sparks is produced.

Summary and Conclusions.

From these investigations it seems clear that the enormous incidence of tuberculosis among the grinders and polishers in this factory, indicated by Dr. Drury's study, is by no means surprising and that it is due primarily to the hazards of wet grinding.

No dust determinations were made in the polishing shops, on account of the lack of suitable electrical connections for operating the dust-sampling apparatus. The polishing wheels, were, however, equipped with an excellent exhaust system. In the case of the dry-grinding shop, which would naturally be much more dusty than a polishing shop, a similar exhaust system proved eminently satisfactory as a preventive of dust dissemination, the air showing an average of only 154,500 one-fourth standard-unit particles per cubic foot. In the wet-grinding shops, on the other hand, only 1 sample out of 32 showed less than 1,000,000 such particles, and only 12 less than 10,000,000, the general average being 15,800,000 one-fourth standard-unit particles per cubic foot. This is one of the highest values ever recorded in any industrial establishment.

It seems evident that the protection afforded by wet grinding, as compared with dry grinding, is in this instance illusory. In order to facilitate rapid work the operators are tempted to cut down the amount of water supplied to the wheel; and in grinding a heavy object like an ax upon a wheel of soft natural sandstone the worker presses so heavily upon the wheel that the superficial film of water is pushed back behind the ax and the outer surface of moist stone is ground off, exposing a dry surface, which in its turn is abraded and discharged as atmospheric dust. The danger is increased by the fact that rapidly revolving wet wheels must be rotated upward toward the face of the worker. The principle of using moisture to eliminate industrial dust is no doubt a sound one, as exemplified in the measures taken for the protection of the miners in South Africa by the use of sprays. The present study merely emphasizes the fact that the efficacy of a process of this sort must be checked up by laboratory tests in order to determine its real effectiveness.

It is evident that wet grinding on sandstone wheels, as practiced at the ax factory studied, is an exceedingly hazardous process, and that the substitution of dry grinding with an efficient exhaust system (or possibly the use of wet grinding on artificial abrasive wheels of a harder nature) is clearly indicated as a measure for the protection of the workers against respiratory disease.